Technical review of the methods used for MoFUSS simulated f_{NRB} estimates versus CDM Tool 30

Report

Client: C-Quest Capital

Date: 30 October 2023

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1. Introduction

This report entails a technical review of certain aspects pertaining to the comparison of the MoFUSS model and CDM Tool 30 guideline for estimating fraction of non-renewable biomass (fNRB). The fNRB serves as a metric to quantify the surplus amount of wood that is harvested beyond a landscape's innate rate of regeneration. To illustrate, if wood is harvested at a rate equal to or below its natural regrowth rate, the harvesting process is sustainable. However, in many countries, where communities heavily rely on fuelwood and charcoal, the extraction of wood often exceeds the landscape's regenerative capacity. This unsustainable practice results in a gradual decline in tree cover over time, leading to landscape degradation and potentially contributing to long-term deforestation.

Efforts aimed at facilitating the transition to more efficient cooking practices play a pivotal role in mitigating forest degradation, as well as curbing emissions that contribute to climate warming. This is achieved by preserving trees that would have been harvested without such interventions. Consequently, carbon emissions that would have been released as CO2 remain sequestered in these standing trees. To maintain the credibility of carbon emission reductions resulting from clean cooking interventions, it is imperative to establish accurate estimates of fractional non-revenue biomass (fNRB). This is because authentic emission reductions can only be attributed to the proportion of harvested wood that would not have regenerated naturally. Higher fNRB values indicate that a substantial portion of wood harvest is non-renewable, enabling successful interventions to claim more substantial emission reductions.

Conversely, lower fNRB values signify that a smaller fraction of wood harvest is non-renewable, consequently leading to fewer emission reductions claimed by interventions. However, when projects rely on fNRB estimates that surpass the actual value, they inadvertently assert greater emission reductions than their projects genuinely accomplish. This misrepresentation undermines mitigation efforts and poses a risk to the reputation of all clean cooking activities.

2. Motivation

Ensuring the integrity of emissions reductions is considered vital for the effective functioning of a carbon market, underscoring the significance of accurate fNRB estimates. Existing literature that supplies country-specific fNRB estimates is perceived as outdated. Consequently, the UNFCCC has initiated research endeavors to address this gap and establish updated fNRB default values. The MoFUSS assessment has been harnessed for this purpose.

However, a noticeable discrepancy arises when comparing the 'old' and 'new' fNRB estimates, particularly in comparison with those derived from different models. Considering these disparities, the UNFCCC has made the assessment conducted for the new default values open for public commentary. This step is taken to ensure that while the aim is to attain values that are conservative, accuracy of the values remains a paramount objective.

3. Comparison of methods

The fNRB serves as an indicator of the quantity of wood that is harvested in an unsustainable manner within a specific area, signifying that it cannot regenerate quickly enough to meet current demand. Estimating the fNRB necessitates an understanding of the available wood resources for harvesting (total woody biomass), the actual quantity being harvested (consumption), and the amount regenerating (renewable biomass).

Various approaches can be employed to address this estimation. This document serves to offer a comparative assessment of the MoFUSS and CDM Tool 30 v4.0 models concerning the estimation of fNRB in each context.

Comparing estimations derived from two distinct modeling techniques inherently presents challenges. Nevertheless, it is essential to recognize the significant influence of numerous factors, such as differences in methodology, input data, and underlying assumptions and nuances, alongside the associated uncertainties.

3.1. CDM Tool 30 v4.0

The CDM Tool employs a methodology that relies on forest cover extent within areas considered accessible for harvesting (excluding protected and geographically remote areas) to calculate the available wood resources. Mean Annual Increment (MAI) growth rates, specific to various ecological zones and age categories of stands, are then applied to the accessible forest to determine the quantity of wood that regenerates. Additionally, per capita consumption rates, derived from official statistics and country-specific data, are used to estimate the amount being harvested.

The calculation of non-renewable biomass (NRB) involves finding the disparity between consumption and renewable biomass. The fNRB is obtained as the ratio of NRB to the total woody biomass. This methodology can be applied to various contexts, such as project areas or administrative levels, including districts, provinces, or national scales. The CDM Tool provides a snapshot fNRB estimate for the harvest, growth and consumption occurring in a one-year period. It is essential to underscore that CDM Tool 30 operates as a methodological guideline for fNRB estimation, allowing for flexibility in its application and the incorporation of diverse assumptions and nuances, provided they are justifiable and contribute to more accurate estimations.

3.2. MoFUSS

The MoFUSS model leverages above-ground biomass (AGB) data extracted from historical AGB maps dated 2010. A biomass growth function is applied with an estimate of wood harvest, which incorporates a pressure index, to ascertain the present availability of wood resources. This evaluation is conducted at a pixel scale with a specified resolution. The regional and global models use a 1 km x 1 km pixel whereas sub-national or project-scale models we could use higher resolutions like, 100 m or 30 m. For each pixel, consumption values are determined by employing population density maps, an urban/rural population density threshold, estimated percentages denoting the rural and urban populations utilizing wood resources, and a default per capita consumption rate.

The calculation of non-renewable biomass (NRB) is achieved through the comparison of estimated AGB values between the current period and the preceding one. A negative AGB value is classified as NRB, while a positive AGB value is categorized as renewable biomass (RB) and is assigned a value of zero. The fNRB for each pixel is calculated as the quotient of NRB divided by consumption.

MoFuSS is a complex model, demanding specialized expertise to comprehend and interpret the input data, interim outputs, and ultimate findings. Moreover, MoFUSS is used to produce predicted estimates of the fNRB for future time periods up to 2050.

4. Inputs and assumptions

Subsequent sections of this document offer detailed comparisons pertaining to input data, assumptions and nuances utilized for the estimation of tree cover, accessibility, renewable biomass, population, and consumption. These comparisons aim to highlight differences that could lead to discrepancies in fNRB estimates by the different studies.

Regarding input data, the MoFUSS model depends on various spatial input datasets, each characterized by differing resolutions, each contributing its unique level of uncertainty, and further compounded by any necessary adjustments in resolution. In contrast, the CDM Tool 30 and its application by C4 EcoSolutions rely on a more streamlined set of inputs, of which only one is a spatial set, simplifying the model and resulting in a lower overall level of uncertainty related to input data.

4.1. Tree cover

Different approaches are taken by CDM Tool 30 and MoFUSS, specifically CDM Tool 30 requires tree cover extent data in hectares (ha) whereas MoFUSS uses above ground biomass (AGB) in tonnes per ha (t/ha).
The CDM Tool 30 presents three distinct options for acquiring tree cover extent data, the most recent FAO Global Forest Resources Assessment, official statistics, and project specific survey data.

C4 EcoSolutions, in its application of the CDM Tool 30, opts for the utilization of Hansen spatial tree cover data as a remote sensing option. This dataset is chosen because it supplies comprehensive information encompassing total tree cover, primary tree cover, and tree cover gain. It boasts recent, validated, and verifiable data, corroborated by other reputable sources. An element of uncertainty associated with the Hansen data set pertains to the tree cover density threshold applied. In instances where specific data regarding tree cover densities for a region, ecological zone, or land cover class is available, it is employed. In cases where such data is absent, a recommended standard threshold of 30% is applied. It is worth noting that the extent of tree cover serves as the foundational component for calculating fNRB, as both accessibility and biomass growth rely upon it.

Conversely, the MoFUSS model utilizes above-ground biomass (AGB) maps obtained from the World Conservation Monitoring Centre (WCMC) dated 2010 as their baseline. These maps are utilized to project future AGB estimates up to 2050. However, it is important to acknowledge that the WCMC maps lack validation and comparability with other available above-ground biomass maps. Furthermore, there is no reported model accuracy for the future AGB estimates in the main document or suggested background reading. While the researchers express intentions to refine AGB estimations in future work, the current estimates may potentially harbor inaccuracies that could impact the fNRB assessments.
Notable disparities emerge when considering the utilization of estimated or projected data, as seen in the MoFUSS model, as opposed to the use of published data, as demonstrated in C4 EcoSolutions' application of CDM Tool 30. The uncertainties inherent in the estimation model employed by MoFUSS to determine AGB have the potential to result in both inaccuracies, consequently impacting the estimation fNRB. In contrast, the utilization of published remote sensing data, as seen in C4 EcoSolutions' approach, helps mitigate these uncertainties.

4.2. Accessibility

Accessibility plays a crucial role in estimating areas suitable for wood harvesting. The CDM Tool 30 and MoFUSS models employ distinct approaches to assess accessibility.

CDM Tool 30 operates by excluding protected areas and geographically remote regions from the tree cover extent. The fNRB is then computed using solely the accessible tree cover.

Regarding protected areas, C4 EcoSolutions relies on the World Database on Protected Areas (WDPA) in conjunction with the International Union for Conservation of Nature (IUCN) categories to identify regions designated as protected and unsuitable for wood harvesting. As for geographically remote areas, C4 EcoSolutions utilizes a distance buffer calculated from all classified and non-classified roads found in the OpenStreetMap Database.

The report provided by the MoFUSS research team lacks a comprehensive explanation of the methodology employed to determine accessibility. Nevertheless, a general overview can be synthesized from the document. The MoFUSS approach utilizes a harvest function to ascertain the quantity of wood harvested within a pixel. This function incorporates a Pressure Index, consumption data, and the overall wood fuel generated as a by-product of deforestation. The harvest amount calculated is then subtracted from the Above Ground Biomass (AGB) growth to derive the current AGB, from which the fNRB is subsequently determined. Accessibility is integrated into the Pressure Index.

To delineate accessibility, a cost-distance analysis is applied from populated areas to establish a pressure index for each pixel. This analysis encompasses the application of a friction factor to each pixel, signifying the difficulty associated with harvesting in specific areas. All pixels are considered accessible, but different friction factors are assigned to different regions. For instance, a friction factor of 90% is imposed on protected areas. The precise methods for obtaining these friction factors and pressure indices are not elaborated upon in the MoFUSS developers' report, which makes direct comparisons with the CDM Tool or C4 EcoSolutions' approach challenging. However, the pressure index maps generated may require validation and verification. The dynamics of growth, conversion, and movement in rural and urban settlements can render this a complex estimation, especially for future projections. Additionally, providing justification for the cost-distance function and friction factors applied to different pixels may prove beneficial.

4.3. MAI

Mean annual increment (MAI) is an indication of the growth rate of woody biomass. This is used to determine renewable biomass.

CDM Tool 30 stipulates that an MAI factor is applied to the accessible forest extent to determine the amount of woody biomass that regenerates annually. The Tool stipulates numerous sources for MAI of which one is applicable to a spatial disaggregation of data according to ecological zone and age of stand, the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for “Above-ground biomass growth rates for different ecological zones” (Chapter 4, Table 4.9). The tool provides the following instructions:

a) Use a weighted average based on the forest area of three categories (i.e., primary forests, above and below 20 years secondary forests), if such data is available. Otherwise, use a simple average of the two age categories of secondary forests or a simple average.
b) The most recent available data shall be used. However, the vintage of the above data shall not be before the year 2000.
c) It is required to determine MAI values for different sub-categories of forest areas and other land areas. However, in the absence of the local data in the country, global data (such as 2019 Refinement to 2006 IPCC Guidelines) or data of similar ecological zones in other regions may be used with due justification.
d) Further, if the MAI value for other land areas is not available in a country while only the MAI value for forest areas exits, the MAI value for forest areas may be used as the MAI value for other land areas with due justification.

C4 EcoSolutions' methodology involves a systematic dissection of tree cover into global ecological zones. This dissection permits the application of specific Mean Annual Increment

(MAI) values that correspond to various ecological zones. Furthermore, data pertaining to primary tree cover and tree cover gain, derived from Hansen spatial data spanning from 2000 to 2020, is harnessed to estimate the proportion of total tree cover falling into distinct categories, such as primary cover, trees below 20 years of age, and trees above 20 years of age. As a result, the applicable MAI value, when dissected according to ecological zone and age category, can be accurately applied to a specific ecological zone and age group. This refinement significantly enhances the precision of biomass growth estimation based on ecological zone and age, thereby improving the overall accuracy of the assessment. Subsequently, a weighted average of the MAI values for each ecological zone and age category is calculated and applied to the accessible forest extent to determine the quantity of renewable biomass.

MoFUSS employs a growth function that determines the pixel-level Above Ground Biomass (AGB) in a future time-step by applying a generic logistic function to the current AGB. This function relies on two constants: "rmax," denoting the maximum growth rate for specific land cover types, and "K," representing the maximum woody biomass for those land cover types. Rmax values are acquired for different ecological zones, land cover classes, and age of stands from the 2019 Refine of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The highest growth rate among the three age categories of stands, corresponding to trees below 20 years, is selected. The maximum stock estimates, or K values, are sourced from WCMC.

The sensitivity of the growth function to the "rmax" and "K" constants means that any uncertainty in these values can result in inaccurate growth estimations. Additionally, the source and accuracy of the growth function are not provided. Although certain measures have been implemented, such as using standard deviations and Monte Carlo Simulations, to enhance the accuracy of the constants, using a maximum value for "rmax" irrespective of the age of stands may still introduce inaccuracies by potentially overestimating the growth of trees older than 20 years.

Furthermore, MoFuSS has the capacity to simulate future tree cover loss resulting from drivers unrelated to wood fuel demand, such as agricultural expansion. However, it does not predict future degradation. In regions unaffected by future tree loss, the simulation allows trees to reach their full potential unless impacted by wood fuel harvesting. Nevertheless, such regions may still be affected by factors contributing to degradation, which can reduce tree growth even in the absence of wood fuel demand. Consequently, these areas may never reach the "K" value. Consequently, the simulations could overestimate regrowth while underestimating fractional non-revenue biomass (fNRB).

4.4. Consumption

The CDM methodology specifies that the estimation of biomass consumption should encompass wood fuel and charcoal used for domestic purposes, in addition to timber and industrial consumption. The method provides several options for acquiring the data necessary for calculating consumption rates, including baseline data, official statistics, peer-reviewed literature, surveys, or the utilization of a default value of 0.4 t/capita /year.

C4 Eco-Solutions employs an official and systematic approach to determine consumption on a national or administrative scale. This method relies on official statistics sourced from the FAO Statistics database. Specifically, consumption data for wood fuel, wood charcoal, industrial roundwood, sawn wood, veneer sheets, and wood-based panels is gathered for each country, with data pertaining to the year 2021, the most recent available.

Subsequently, a per capita consumption rate for each consumption category is computed by dividing the respective consumption figures by the total population of 2021. This approach ensures the derivation of a more conservative per capita consumption rate, accommodating demographic variations and accounting for non-users. These per capita consumption rates are then applied to the total population of the year in which the fNRB is calculated, such as 2022.

The MoFUSS model adopts a pixel-scale approach to determine consumption, divided into two primary segments: quantifying the consumption quantity and pinpointing consumer locations. This process relies on two essential parameters: the number of users and the amount per user.

A spatial population distribution map is utilized, incorporating a predefined threshold for urban and rural population density, derived from UNDESA's estimate. The World Health Organization's (WHO) Global Household Energy model is employed, providing estimations for the number and percentage of users in rural and urban demographics who rely on fuelwood and charcoal for each country from 2009 to 2021. The percentages obtained from WHO are subsequently applied to both rural and urban demographics, resulting in the calculation of the number of consumers for individual pixels. The default per capita consumption rate is then applied to determine the amount of wood consumed per pixel. These pixel-level values are subsequently aggregated to encompass various administrative boundaries.

Several differences in consumption estimation between the two models deserve attention. Firstly, the issue of predicted versus published data, as discussed at 'tree cover' above, is raised once more. This is applicable to the population density and fuelwood and charcoal usage.

Secondly, the MoFUSS model opts not to account for commercial products, grounded on the assumption that these products originate from sustainable plantations and constitute less than 10% of total wood consumption. In contrast, the Tool prescribes their inclusion. C4 Eco-Solutions, utilizing tree cover extent data from Hansen, which does not exclude plantation tree cover, thus includes commercial products. This approach may yield larger consumption estimates in comparison to MoFUSS.

Thirdly, the MoFUSS model departs from employing country-specific per capita consumption rates, opting instead for a uniform default value of 0.4 for all countries. This choice is justified by its alignment with the range of averages drawn from country Project Design Documents (PDDs) and surveys. Nevertheless, this approach may introduce inaccuracies, as a standardized value may not capture the distinct consumption practices specific to individual countries or regions.

A fourth distinction emerges in the utilization of a spatial population distribution map with an applied threshold for urban population density, based on estimates from UNDESA, in contrast to using total population figures without differentiation between rural and urban demographics. The uncertainty associated with the population distribution map and the urban threshold may introduce inaccuracies, particularly in the classification of densely populated rural areas as urban, which could then result in incorrect consumption calculations.

Furthermore, the models maintain consistency in rural and urban areas, considering only population growth for future estimations. While this may introduce a degree of inaccuracy in future predictions, it is recognized as a challenging aspect to model. Similarly, the assumption that percentages of fuelwood usage percentage and per capita consumption remains constant for future projections up to 2050, may introduce further inaccuracies given the changes in fuelwood use.

5. Suggestions made by the MoFUSS team on the CDM Tool and corresponding responses

The documents titled "CDM-MP92-A07 Information Note v1.0" and "Updated fNRB values for Wood fuel Interventions" delineate the MoFUSS model and its constituent elements comprehensively. Furthermore, the creators of the MoFUSS model have, in said former document, proffered two recommendations for enhancing the CDM methodology:

Point 1:

"Tool 30 provides guidelines for calculating fNRB without using explicit spatial analyses. The calculation requires project developers to have access to estimates of forest areas and forest productivity defined by the mean annual increment or MAI. For forest areas, the tool suggests using data from a 2000 FAO publication. However, this is both outdated and inadequate because it ignores trees outside forests, which are important sources of wood fuel. If some version of TOOL30 is to be included in future methodologies, we suggest using more recent sources of land cover data that also account for trees outside forests. For example, the European Union's EU's flagship Copernicus programme provides free and open global land cover maps through 2019 which include 12 categories of forested land as well as shrubland, grassland, croplands, and other areas that are likely to include trees outside forests."

The statement above presents a measure of accuracy in its reference to the utilization of outdated data concerning forest cover and mean annual increment within the Tool. Notably, the Tool offers flexibility by accommodating various land classes, which allows for the inclusion of trees beyond traditional forested areas. However, it is worth noting that this data may not be readily available at a national level. The statement's assertion of inaccuracy lies in its omission of the explicit requirement, outlined in the latest version of the tool, that up-to-date data must be utilized, with a cutoff not exceeding the year 2000. A 2020 version is readily accessible, rendering it a viable alternative. Furthermore, the Tool offers two additional methods for determining forest cover: official statistics and project-specific survey data.

As previously mentioned, applying any model necessitates certain assumptions. In C4 EcoSolutions's utilization of CDM Tool 30 v4.0, the approach entails the use of tree cover, encompassing all tree vegetation regardless of land cover classification. This parameter is determined using Hansen spatial data spanning the years 2000 to 2022, providing recent information on tree cover, primary tree cover, and tree cover gain. This approach aligns with option three within the CDM Tool 30 v4.0, which accommodates remote sensing surveys as a valid method.

Point 2:

"For biomass growth rates, TOOL30 recommends using Table 4.9 from the IPCC's 2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories. This is a more recent source of data, which makes it more appropriate for current estimates. However, the data presented for each land-use and land-cover category includes up to three values that vary with the age of the forest area in question. These growth rates can differ by up to a factor of 10. Project developers can obtain wildly different fNRB values depending on which growth rates are used. As with forest and non-forest areas, clearer guidance about the use of age-based MAI values is required if a version of TOOL30 is going to be used in future methodologies. For example, the Copernicus data cited above could be integrated with tree cover data from a source like Global Forest Watch to create less ambiguous estimates of growth rates."

C4 EcoSolutions' approach consciously avoids the application of a single Mean Annual Increment (MAI) value across the entire forest, regardless of ecological zone or age. Instead, the methodology adopted by C4 EcoSolutions entails the disaggregation of tree cover into global ecological zones. This dissection allows for the application of distinct MAI values corresponding to different ecological zones. Additionally, the data on primary tree cover and tree cover gain sourced from Hansen spatial data for 2000 to 2020 is leveraged to estimate the proportion of total tree cover falling into categories such as primary, below 20 years of age, and above 20 years of age.

Consequently, the applicable MAI value, when dissected by ecological zone and age of the stand, can be precisely applied to a specific ecological zone and age category. This refinement results in a more precise estimation of biomass growth based on ecological zone and age, thus enhancing the accuracy of the assessment.
The developers of MoFUSS further highlight a few differences between the MoFUSS model and the CDM model:

Point 3:

"While TOOL30 defines biomass consumption on a jurisdictional basis (e.g., districts, counties, or countries), the model used in the assessment calculates it at pixel level (tons of dry biomass per hectare or km2) and then uses this data to derive results at larger aggregation levels"

Discrepancies in scale introduce inherent uncertainties, particularly concerning input data, which can notably impact estimations. Variation in resolution of pixel-based inputs and outputs is one issue pertaining to scale. Another issue aligns with the differences obtained by applying a bottom-up pixel aggregation approach versus a boundary approach.

Point 4:

"Though both TOOL30 and the MoFuSS use biomass growth parameters such as Mean Annual Increment (MAI) and Current Annual Increment (CAI) respectively, to define long-term average wood growth, in case of TOOL30 biomass growth parameters are applied to the entire land cover categories regardless of their conditions. In contrast, the new model relies on growth functions, which are specific to land cover type and ecological zone and vary with current stock levels. The model applies these functions at the pixel level, so that every pixel has a unique woody biomass production function. Therefore, it is expected that the model simulates biomass harvest and regrowth after harvest more realistically".

While the approach described may theoretically lead to more realistic growth estimates, the accuracy of the growth function and constants must be accounted for. The uncertainty of these has been addressed in the section on MAI. The approach followed by C4 EcoSolutions does disaggregate the land into region and ecological zone and the tree cover into age of stand to apply the IPCC MAI values correctly and as accurately as possible.

Point 5:

"TOOL30 only considers accessibility in the sense that it removes protected areas from consideration of biomass supply. MoFuSS also accounts for protected areas but goes further by considering physical accessibility based on topographical features and the effort that wood fuel users must expend to access sources of woody biomass."

The statement contains an inaccuracy, as the CDM Tool 30 indeed accommodates and furnishes guidelines for defining geographically remote areas by considering factors such as proximity to roads or rivers. This provision is explicitly articulated on page 11 of CDM Tool 30 v4.0 as follows:

"To define 'geographically remote area', DNAs/PPs may consider proximity to roads or rivers. For example, forests/other wooded lands that are beyond the average distance travelled to collect fuelwood can be considered non-accessible. The information of the average travel distance may be sourced from national studies or peer-reviewed literature, or surveys in the project area. All areas that are accessible to either the forest industries or to individual households are ‘accessible’. Therefore, wood extraction by the forest industries and fuelwood collection by individual households should both be considered when estimating the ‘non-accessible areas.”

C4 EcoSolutions employs recent road maps that encompass both classified and unclassified roads, and a 2.5 km distance buffer is implemented, designating that tree cover within this buffer area is considered accessible. This buffer's determination was derived from peer-reviewed literature. Furthermore, the IUCN classification of protected areas is considered in the analysis to ensure that only protected areas where harvesting is most unlikely are excluded from the accessible forest area.

6. Conclusion

Considering the points raised, it would not be prudent to presume that the fNRB estimates derived from the MoFUSS model hold accuracy across all countries and administrative boundaries. The intricate nature of the model necessitates numerous estimations applied to the input data and analytical methods. While the methodology may be theoretically justifiable, the absence of validation and verification for these estimations may indicate a degree of inaccuracy, potentially leading to incorrect fNRB estimations. The variance between these values and the prior WISDOM model further supports this notion, considering that similar approaches were undertaken.

7. Comments

It may be prudent to prioritize the validation and verification of the estimated Above Ground Biomass (AGB) maps for accuracy before officially adopting the fNRB estimates derived from them as defaults. Inaccuracies in the AGB inputs can have a cascading effect, introducing inaccuracies in the fNRB estimations, particularly given its sensitivity to changes in AGB.

Likewise, the precision of the estimations related to population, consumption, tree growth, pressure index, and harvest should undergo validation and verification to ensure reliability.

Furthermore, it is essential to consider the UNFCCC Board's directive that these default estimates should align with the methods outlined in "TOOL30 Calculation of the fraction of non-renewable biomass." There may be discrepancies in this alignment, particularly since the determination of accessibility and harvest relies on a notably different approach.